(54) **Radar apparatus with a simplified construction**

Radaranlage mit vereinfachter Bauart

Appareil radar à construction simplifiée

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The present invention relates to radar apparatuses and, more particularly, to a radar apparatus for use in automobiles.

[0002] Under recent circumstances in which automobile accidents are increasing yearly with the increase of automobiles, it has become necessary for an automobile to be equipped with an apparatus supporting safety operation. Such an apparatus should be capable of warning a driver of a possible crash, measuring a ground speed accurately and controlling the engine properly while the automobile is driven on a wet road.

2. Description of the Related Art

[0003] Conventional radars for measuring a relative speed and distance of an automobile with respect to a target object include a frequency modulated continuous wave (FMCW) radar and a pulse Doppler radar. In an FMCW radar, as shown in Fig. 1, a triangular baseband signal is supplied to a transmission voltage controlled oscillator (VCO) 10 for frequency modulation. A resultant high-frequency signal obtained from the voltage controlled oscillator 10 is transmitted via a transmission antenna 11. A portion of the high-frequency signal is branched off to a reception mixer (MIX) 12 supplied with a received signal received via a reception antenna 13. According to this arrangement, a beat signal commensurate with a distance from a target object and a relative speed with respect to the target object is obtained. Since such a construction enables a significantly simple signal processing unit to provide a relative speed signal and a distance signal, it is extensively being applied to radar apparatuses such as an automobile radar apparatus which are expected to be small and inexpensive.

[0004] In one specific implementation of a radar apparatus illustrated in Fig. 2, a switch (SW) 16 is provided between the reception antenna 13 and the reception mixer 12 so as to prevent a signal-to-noise ratio from beign degraded due to a leak of the triangular modulating signal to the reception side and to attenuate 1/f noise provided by the reception mixer (MIX) 12. The switch 16 may be operated according to a drive signal (LO) from an oscillation source 18 so as to subject the received signal to frequency conversion. The received signal output from the reception mixer (MIX) 12 is supplied to a second mixer 22 via a band-pass filter (BPF) 20. In the second mixer 22, the received signal is subject to frequency conversion again, using the drive signal (LO), so that a beat signal is obtained.

[0005] For example, a frequency f_0 of a transmitted signal output by the voltage controlled oscillator 10 is on the order of 10 - 100 GHz, a frequency f_{SW} of the switch drive signal (LO) is on the order of 10 - 100 MHz and a beat frequency $f\delta$ produced by the transmitted signal and the received signal is below the order of 10 - 100 KHz. The frequency of the triangular wave is on the order of 100 - 1000 Hz. The amplitude of the transmitted signal supplied to the reception mixer 12 varies due to the frequency response of the VCO 10 and the line. The frequency of the amplitude variation is 100 - 1000 Hz. Since the reception mixer 12 has an AM demodulating function as well as the frequency conversion function, the output signal of the reception signal 12 inevitably includes noise in the form of the amplitude variation.

[0006] The frequency of the received signal received via the reception antenna 13 is given by $f_0 + f\delta$. As a result of the frequency conversion using the switch 16, a received signal having frequencies between $f_0 + f\delta - f_{SW}$ and $f_0 + f\delta + f_{SW}$ is produced. Accordingly, the reception mixer 12 produces an IF signal having frequencies between $f_{SW} - f\delta$ and $f_{SW} + f\delta$. The IF signal contains a noise in the form of amplitude variation having a frequency on the order of 100 - 1000 Hz. Since the IF signal has a frequency on the order of 10 - 100 MHz, the noise in the form of the amplitude variation is removed by the band-pass filter 20. The mixer 22 subjects the IF signal having the noise removed to frequency conversion so as to obtain the beat signal having a frequency $f\delta$.

[0007] The antennas 11 and 13 must have a size commensurate with a beamwidth capable of covering a single traffic lane so as not to detect a reflected wave from a non-target object outside a detection range of the radar. For example, given that the detection range is 100 m, and the width of a lane is 3.6 m, the beamwidth required to keep out a reflected wave from a vehicle driven in another lane 100 m ahead would be 2.1 degrees. As is well known, the relationship between the beamwidth B and the diameter D of the reflector antenna is given by

$$D \approx 70 \times \lambda/B$$

[0008] Assuming that the beamwidth is 2.1 degrees and the frequency is 60 GHz (the wavelength = 5 mm), the diameter D of the antenna is 167 mm, according to the above equation.

[0009] In the 100 m distance, an area covered by the radar is determined by a product of gain drops of the transmission and the reception antenna at a given angular separation. Thus, the diameter may actually be smaller than the result obtained according to the above equation. Antennas having a diameter of about 110 mm are usually used.

[0010] Desirably, an automobile radar apparatus is designed so as not to detract from the aesthetic design of the automobile body. For optimum matching with the design, the smaller the radar apparatus, the better. Also, an automobile radar apparatus is ideally inexpensive in order to be available to the general public. However, requirement for concurrent transmission and reception im-

poses the use of both the transmission antenna and the reception antenna, so that it is difficult to achieve reduction of the size and price of an automobile radar apparatus according to the conventional technology.

[0011] As shown in Fig. 3, one approach to reduce the size of the radar apparatus is to use a directional coupler 26 so that a transmission and reception antenna 24 can be shared. In the circuit of Fig. 3, a portion of the transmission power is supplied to the transmission and reception antenna 24 via the directional coupler 26. An isolation capability of the directional coupler 26 is utilized to supply a local power to the reception mixer 12. The degree of coupling of the directional coupler 26 is set below 10 dB so as not to draw an excessively large power to the reception mixer 12 in consideration of the withstand capability of the reception mixer 12. Accordingly, a problem with this approach is that the voltage controlled oscillator 10 is required to output a significantly larger power than an actual output power needed to attain a satisfactorily long detection range. For example, assuming that the power actually radiated by the antenna is 10 mW, a power exceeding 100 mW is needed. Although an output on the order of 10 - 100 mW can be easily obtained by high-output devices such as an IMPATT diode and a Gunn diode in the milliwave band, an output exceeding 100 mW cannot be obtained easily by the present device technology. It is also to be noted that devices such as the IMPATT diode and the Gunn diode are quite expensive.

[0012] Since the isolation capability of the directional coupler 26 is used in the approach of Fig. 3, the local input power varies due to the antenna impedance. For this reason, it is difficult for the reception mixer 12 to perform stable frequency conversion.

[0013] One problem that arises as the number of vehicles equipped with an automobile radar apparatus increases is radio interference from other vehicles. Since automobile radars share generally the same frequency band, radars carried on automobiles driven on the opposite lane may cause radio interference so that the target object ahead of the user driving on the same lane becomes lost on the radar.

[0014] Conventional approaches to prevent radio interference include the use of a 45-degree linearly polarized wave antenna or a circularly polarized wave antenna. Polarization discrimination provided by such types of antennas is used to attenuate radio interference from other vehicles. However, polarization discrimination provided by such types of antennas is 20 - 25 dB at best. As the number of vehicles equipped with a radar increases, the interfering signal level increases so that the conventional technology cannot provide a satisfactory performance of the radar.

[0015] The article entitled Switching system for single antenna operation of an S-band FMCW radar by J. A. McGregor, E. M. Poulter and M. J. Smith and published in 8049 IEEE Proceedings Radar, Sonar and Navigation, 141(1994) August, describes a ground based S-band ocean surface remote sensing FMCW radar that has been adapted for single antenna operation by alternately switching the single antenna between the transmitter and the receiver. Even though this frequency modulated interrupted continuous wave (FMICW) system is no longer a true continuous wave radar, the essential properties of the FMCW waveform are preserved, provided some conditions on the switching speed and the FMCW parameters are met.

[0016] The article An FM-CW radar module with front-end switching heterodyne receiver by T. Saito, N. Okubo, Y. Kawasaki, O. Isaji, and H. Suzuki and published in the IEEE MTT-S Digest 1992 relates to a FM-CW radar module that generate sidebands by switching a HEMT front-end using heterodyne detection for FM-AM conversion noise reduction.

[0017] Front-end switching modulates the amplitude of the received signal by a square-wave signal to generate a sideband at either side of the received signal. The beat signal is converted from the baseband to the IF by mixing the transmitted and received signal using a millimeter-wave mixer. The beat frequency and FM-AM conversion noise are present in the baseband, but only the beat signal remains in the IF band. Since the beat signal is not affected by FM-AM conversion noise, the radar module has a high S/N characteristic (Fig. 3)

[0018] Using this technique, the low-frequency noise generated by a millimeter-wave mixer, which is the second largest noise contributor in FM-CW radar, is reduced at the same time. The beat signal is converted to an IF band where the low-frequency noise level is low. The low-frequency noise level of an IF band is 10 dB lower than that of the baseband frequency.

[0019] US 4,739,330 describes a frequency modulation radio altimeter that has a directional antenna which is connected to a transmission-reception switch controlled by a signal generator. The generator delivers periodic signals whose recurrence period is proportional to the delay time of the ground echo. The transmitter includes a radio frequency modulator modulated in frequency by a saw tooth signal whose recurrence period is proportional to the delay time of the ground echo. A homodyne receiver includes circuits for acquiring and tracking the ground echo signal, and supplies an output signal representative of the altitude and a control signal which is supplied to the inputs controlling the recurrence period of the transmission modulator and of the generator controlling the transmission-reception switch.

SUMMARY OF THE INVENTION

[0020] Accordingly, an object of the present invention is to provide radar apparatuses in which the aforementioned problems are eliminated.

[0021] Another and more specific object of the present invention is to provide a radar apparatus to a reduced size and cost in which transmission and recep-

tion can be performed by a single antenna.

[0022] Still another object of the present invention is to provide a radar apparatus in which interference from other apparatuses can be detected and removed.

[0023] In order to achieve the aforementioned objects, there is provided a vehicle mounted radar apparatus according to the appended claim 1. Preferred embodiments are defined in the dependent claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0024] Other objects and further features of the present invention will be apparent from the following detailed description when read in conjunction with the accompanying drawings, in which:

Fig. 1 shows a construction of a conventional FM-CW radar;
Fig. 2 shows another construction of a conventional FMCW radar;
Fig. 3 shows still another construction of a conventional FMCW radar;
Fig. 4 is a block diagram of a radar apparatus according to a first example;
Fig. 5 shows a frequency spectrum of an ID signal;
Figs. 6A, 6B and 6C show constructions of antenna sharing means;
Figs. 7A, 7B and 7C are timing charts for signals occurring in the apparatus shown in Fig. 4;
Fig. 8 is a block diagram of a radar apparatus according to a second example ;
Fig. 9 is a block diagram of a radar apparatus according to a third example ;
Fig. 10 shows a circuit diagram of an SPDT switch;
Fig. 11 is a block diagram of a radar apparatus according to a first embodiment of the present invention;
Figs. 12A, 12B and 12C are timing charts for signals occurring in the apparatus shown in Fig. 11;
Fig. 13 is a block diagram of a radar apparatus according to a second embodiment of the present invention;
Fig. 14 is a block diagram of a radar apparatus according to a third embodiment of the present invention;
Fig. 15 is a table showing the operation of the radar apparatus according to the third embodiment;
Fig. 16 is a block diagram of a radar apparatus according to a fourth example ;
Figs. 17A and 17B are waveform charts of a voltage applied to a control terminal of the voltage controlled oscillator;
Fig. 18 is a block diagram of a radar apparatus according to a fifth example;
Fig. 19 is a graph illustrating how an interference occurs;
Fig. 20 is a graph illustrating how an interference occurs;

Fig. 21 is a block diagram of a radar apparatus according to a sixth example ;
Figs. 22A and 22B show implementations of interference detecting means;
Fig. 23 is a block diagram of frequency hopping means;
Fig. 24 is a block diagram of a radar apparatus according to a seventh example present invention;
and
Fig. 25 is a block diagram of a radar apparatus according to an eighth example.

DESCRIPTION OF THE PREFERRED
EMBODIMENTS

[0025] Fig. 4 is a block diagram of a radar apparatus according to a first example . Referring to Fig. 4, a triangular baseband signal (Mod) having a frequency of about several kHz is applied to a voltage controlled oscillator (VCO) 30 for frequency modulation. The resultant frequency modulated signal having a frequency f_0 on the order of 10 - 100 GHz is supplied to a transmission switch (SW) 32. A portion of the frequency modulated signal is supplied to a reception mixer 34. The transmission switch 32 is controlled to be opened or closed in accordance with a drive signal output from a switch drive signal source (LO) 35. The drive signal has a frequency f_{SW} on the order of 10 - 100 MHz and is a rectangular wave with a 50% duty factor. When the switch 32 is closed, the frequency modulated signal to be transmitted is supplied to an antenna 38 via antenna sharing means 36.

[0026] The drive signal output from the switch drive signal source 35 is inverted by an inverter 40 and supplied to a reception switch 42. Accordingly, when the transmission switch 32 is open, the reception switch 42 is closed so that a received signal received via the antenna 38 is supplied to the reception mixer 34 via the antenna sharing means 36 and the reception switch 42. The reception mixer 34 produces and outputs the IF signal.

[0027] The frequency of the received signal received via the antenna 38 is given by $f_0 + f\delta$. As a result of frequency conversion by the reception switch 42, a signal having frequencies between $f_0 + f\delta - f_{SW}$ and $f_0 + f\delta + f_{SW}$ is obtained. Accordingly, the reception mixer 34 produces the IF signal having frequencies between $f_{SW} - f\delta$ and $f_{SW} + f\delta$ and having the frequency spectrum as shown in Fig. 5.

[0028] The IF signal is subject to FM modulation in order to detect the frequency $f\delta$. The frequency $f\delta$ of a period in which the frequency increases and the frequency $f\delta$ in a period in which the frequency decreases are used as a basis to calculate the relative speed and the distance with respect to the target object.

[0029] The antenna sharing means 36 may be implemented by a circulator 44 as shown in Fig. 6A, a 90° hybrid circuit 45 as shown in Fig. 6B or a branch circuit

46 as shown in Fig. 6C. The attenuation provided by the circulator 44 is approximately 2 - 3 dB. The attenuation provided by the 90° hybrid circuit 45 and the branch circuit 46 is approximately 3 - 4 dB.

[0030] As shown in Fig. 7A, transmission of a signal via the antenna 38 occurs in response to the closing of the transmission switch 32 by the drive signal. The reflected signal as shown in Fig. 7B reflected by the target object arrives at the antenna 38. As shown in Fig. 7C, a portion of the reflected signal is received by the antenna 38 in response to the closing of the reception switch 42.

[0031] Thus, since a single antenna is shared in transmission and reception operations, the radar apparatus produced accordingly can be small and inexpensive.

[0032] Fig. 8 is a block diagram of a radar apparatus according to a second example. Referring to Fig. 8, a triangular baseband signal (Mod) having a frequency on the order of 100 - 1000 Hz is applied to the voltage controlled oscillator (VCO) 30 for frequency modulation. The resultant frequency modulated signal having a frequency f_0 on the order of 10 - 100 GHz is supplied to the transmission switch (SW) 32. A portion of the frequency modulated signal is branched off to the reception mixer 34. The transmission switch 32 is controlled to be opened or closed in accordance with the drive signal output from the switch drive signal source (LO) 35. The drive signal has a frequency f_{SW} on the order of 10 - 100 MHz and is a rectangular wave with a 50% duty factor. When the switch 32 is closed, the frequency modulated signal to be transmitted is supplied to the antenna 38 via the antenna sharing means 36.

[0033] The drive signal output from the switch drive signal source 35 is inverted by the inverter 40 and supplied to the reception switch 42. Accordingly, when the transmission switch 32 is open, the reception switch 42 is closed so that a received signal received via the antenna 38 is supplied to the reception mixer 34 via the antenna sharing means 36 and the reception switch 42. The reception mixer 34 produces and outputs the IF signal.

[0034] The frequency of the received signal received via the antenna 38 is given by f_0 + fδ. As a result of frequency conversion by the reception switch 42, a signal having frequencies between f_0 + fδ - f_{SW} and f_0 + fδ + f_{SW} is obtained. Accordingly, the reception mixer 34 produces the IF signal having frequencies between f_{SW} - fδ and f_{SW} + fδ and having the frequency spectrum as shown in Fig. 5. Due to the AM demodulating function of the reception mixer 34, a noise having a frequency on the order of 100 - 1000 Hz caused by amplitude variation of the frequency modulated signal is contained in the IF signal. By supplying the IF signal to the band-pass filter 50 so that only the frequency band between f_{SW} - fδ and f_{SW} + fδ on the order of 10 - 100 MHz is allowed to pass, the noise having the frequency on the order of 100 - 1000 Hz can be removed. The IF signal is fed to a mixer 52. The mixer 52 produces and outputs a beat

signal having a frequency of fδ by mixing the IF signal having the frequencies between f_{SW} - fδ and f_{SW} + fδ and having the noise removed, with the drive signal having the frequency f_{SW}.

[0035] Fig. 9 is a block diagram of a radar apparatus according to a third example . A triangular baseband signal (Mod) having a frequency on the order of 100 - 1000 Hz is applied to the voltage controlled oscillator (VCO) 30 for frequency modulation. The resultant frequency modulated signal having a frequency f_0 on the order of 10 - 100 GHz is supplied to a single-port double-throw (SPDT) switch (SW) 54. A portion of the frequency modulated signal is branched off to the reception mixer 34. The SPDT switch 54 is controlled to be connected to the VCO 30 while the drive signal output from the drive signal source (LO) 35 is at logical high and to the reception mixer 34 while the drive signal is at logical low. The drive signal has a frequency f_{SW} on the order of 10 - 100 MHz and is a rectangular wave with a 50% duty factor. While the drive signal is at logical high, the frequency modulated signal is supplied to the antenna 38 and output therefrom.

[0036] The received signal received via the antenna 38 while the drive signal is at logical low is supplied to the reception mixer 34 via the SPDT switch 54. The reception mixer 34 produces and outputs the IF signal.

[0037] The received signal received via the antenna 38 has the frequency f_0 + fδ. As a result of frequency conversion by the reception switch 42, a signal having frequencies between f_0 + fδ - f_{SW} and f_0 + fδ + f_{SW} is produced and supplied to the reception mixer 34 which then produces the IF signal having frequencies between f_{SW} - fδ and f_{SW} + fδ and having the frequency spectrum shown in Fig. 5. Due to the AM demodulating function of the reception mixer 34, the IF signal contains a noise having a frequency on the order of 100 - 1000 Hz caused by amplitude variation of the frequency modulated signal. By supplying the IF signals to the band-pass filter 50 so that only the frequency band between f_{SW} - fδ and f_{SW} + fδ on the order of 10 - 100 MHz is allowed to pass, the noise having the frequency on the order of 100 - 1000 Hz can be removed. The IF signal is then fed to a mixer 52. The mixer 52 produces and outputs a beat signal having a frequency of fδ by mixing the IF signal having the frequencies between f_{SW} - fδ and f_{SW} + fδ and having the noise removed, with the drive signal having the frequency f_{SW}.

[0038] The SPDT switch has a circuitry as shown in Fig. 10. Referring to Fig. 10, terminals 55a and 55b are connected to the voltage controlled oscillator 30 and the reception mixer 34, respectively. A terminal 56 is connected to the antenna 38. The drive signal is supplied to a terminal 57. While the drive signal is at logical high, n-channel MOS transistors Q2 and Q4 are ON and n-channel MOS transistors Q1 and Q3 are OFF so that the terminals 55a and 56 are connected to each other and the terminal 55b is grounded. While the drive signal is at logical low, the n-channel MOS transistors Q1 and

Q3 are ON and the n-channel MOS transistors Q2 and Q4 are OFF so that the terminals 55b and 56 are connected to each other and the terminal 55a is grounded.

[0039]   Fig. 11 is a block diagram of a radar apparatus according to a first embodiment of the present invention. Referring to Fig. 11, a triangular baseband signal (Mod) having a frequency on the order of 100 - 1000 Hz is applied to the voltage controlled oscillator (VCO) 30 for frequency modulation. The resultant frequency modulated signal having a frequency f_0 on the order of 10 - 100 GHz is supplied to the transmission switch (SW) 32. A portion of the frequency modulated signal is supplied to the reception mixer 34. The transmission switch 32 is controlled to be opened or closed in accordance with a drive signal obtained by subjecting an output signal from the switch drive signal source (LO) 60 to 1/N frequency division by a frequency divider 62, where N is 5 - 20, for example. The drive signal output from the frequency divider 62 has a frequency f_{SW} on the order of 10 - 100 MHz and is a rectangular wave with a 50% duty factor. When the switch 32 is closed, the frequency modulated signal to be transmitted is supplied to the antenna 38 via the antenna sharing means 36.

[0040]   The drive signal output from the switch drive signal source 60 is supplied to a NAND circuit 64 together with the drive signal output from the frequency divider 62. While the drive signal is at logical low, a signal having a frequency N^*f_{SW} is supplied from the NAND circuit 64 to the reception switch 42. Accordingly, when the transmission switch 32 is open, the reception switch 42 is opened or closed at the frequency N^*f_{SW}. While the reception switch 42 is closed, the received signal received via the antenna 38 is supplied to the reception mixer 34 via the antenna sharing means 36 and the reception switch 42. The reception mixer 34 produces and outputs the IF signal.

[0041]   The frequency of the received signal received via the antenna 38 is given by $f_0 + f\delta$. As a result of frequency conversion by the reception switch 42, a signal having frequencies between $f_0 + f\delta - N^*f_{SW}$ and $f_0 + f\delta + N^*f_{SW}$ is obtained. Accordingly, the reception mixer 34 produces an IF signal having frequencies between $N^*f_{SW} - f\delta$ and $N^*f_{SW} + f\delta$. Due to the AM demodulating function of the reception mixer 34, a noise having a frequency on the order of 100 - 1000 Hz caused by amplitude variation of the frequency modulated signal is contained in the IF signal. By supplying the IF signal to the band-pass filter 50 so that only the frequency band between $N^*f_{SW} - f\delta$ and $N^*f_{SW} + f\delta$ on the order of 10 - 100 MHz is allowed to pass, the noise having the frequency on the order of 100 - 1000 Hz can be removed. The IF signal is then fed to the mixer 52. The mixer 52 produces and outputs a beat signal having a frequency of $f\delta$ by mixing the IF signal having the frequencies between $N^*f_{SW} - f\delta$ and $N^*f_{SW} + f\delta$ and having the noise removed, with the drive signal having the frequency N^*f_{SW} output from the NAND circuit 64.

[0042]   Generally, a semiconductor device contains a 1/f noise. The lower the frequency, the higher the level of the noise. The switching frequency of the reception switch 42 according to the first embodiment described above is configured to be N times that of the switching frequency of the foregoing embodiments so that the 1/f noise generated in the reception mixer 34 is reduced and the S/N ratio is improved.

[0043]   The drive signal closes the transmission switch 32 so as to time the transmission of the transmitted signal via the antenna 38 as shown in Fig. 12A. The signal reflected by the target object arrives at the antenna 38 as shown in Fig. 12B. Reception of a portion of the reflected signal via the antenna 38 is timed as shown in Fig. 12C by closing the reception switch 42.

[0044]   Fig. 13 is a block diagram of a radar apparatus according to a second embodiment. Referring to Fig. 13, a triangular baseband signal (Mod) having a frequency on the order of 100 - 1000 Hz is applied to the voltage controlled oscillator (VCO) 30 for frequency modulation. The resultant frequency modulated signal having a frequency f_0 on the order of 10 - 100 GHz is supplied to the single-port double-throw (SPDT) switch (SW) 54. A portion of the frequency modulated signal is branched off to the reception mixer 34. The SPDT switch 54 is controlled to be connected to the VCO 30 while the drive signal obtained by subjecting an output signal from the switch drive signal source (LO) 60 to 1/N frequency division is at logical high and to the reception switch 42 while the drive signal is at logical low. The drive signal has a frequency f_{SW} on the order of 10 - 100 MHz and is a rectangular wave with a 50% duty factor. While the drive signal is at logical high, the frequency modulated signal is supplied to the antenna 38 via the SPDT switch 54 and output therefrom.

[0045]   The drive signal output from the switch drive signal source 60 is supplied to the NAND circuit 64 together with the drive signal output from the frequency divider 62. While the drive signal is at logical low, a signal having a frequency N^*f_{SW} is supplied from the NAND circuit 64 to the reception switch 42. Accordingly, while the SPDT switch 54 is connected to the reception switch 42, the reception switch 42 is opened or closed at the frequency N^*f_{SW}. While the reception switch 42 is closed, the received signal received via the antenna 38 is supplied to the reception mixer 34 via the SPDT switch 54 and the reception switch 42. The reception mixer 34 produces and outputs the IF signal.

[0046]   The frequency of the received signal received via the antenna 38 is given by $f_0 + f\delta$. As a result of frequency conversion by the reception switch 42, a signal having frequencies between $f_0 + f\delta - N^*f_{SW}$ and $f_0 + f\delta + N^*f_{SW}$ is obtained. Accordingly, the reception mixer 34 produces an IF signal having frequencies between $N^*f_{SW} - f\delta$ and $N^*f_{SW} + f\delta$. Due to the AM demodulating function of the reception mixer 34, a noise having a frequency on the order of 100 - 1000 Hz caused by amplitude variation of the frequency modulated signal is contained in the IF signal. By supplying the IF signal to the

band-pass filter 50 so that only the frequency band between N^*f_{SW} - fδ and N^*f_{SW} + fδ on the order of 10 - 100 MHz is allowed to pass, the noise having the frequency on the order of 100 - 1000 Hz can be removed. The IF signal is then fed to the mixer 52. The mixer 52 produces and outputs a beat signal having a frequency of fδ by mixing the IF signal having the frequencies between N^*f_{SW} - fδ and N^*f_{SW} + fδ and having the noise removed, with the drive signal having the frequency N^*f_{SW} output from the NAND circuit 64.

[0047] The switching frequency of the reception switch 42 according to the second embodiment described above is configured to be N times that of the switching frequency of the first through third embodiments so that the 1/f noise generated in the reception mixer 34 is reduced and the S/N ratio is improved.

[0048] Fig. 14 is a block diagram of a radar apparatus according to a third embodiment of the present invention. Referring to Fig. 14, a triangular baseband signal (Mod) having a frequency on the order of 100 - 1000 Hz is applied to the voltage controlled oscillator (VCO) 30 for frequency modulation. The resultant frequency modulated signal having a frequency f_0 on the order of 10 - 100 GHz is supplied to the single-port double-throw (SPDT) switch (SW) 54. A portion of the frequency modulated signal is branched off to the reception mixer 34. The SPDT switch 54 is controlled to be connected to the VCO 30 while the drive signal output from the switch drive signal source (LO) 35 is at logical high and to the reception switch 42 while the drive signal is at logical low. The drive signal has a frequency f_{SW} on the order of 10 - 100 MHz and is a rectangular wave with a 50% duty factor. While the drive signal is at logical high, the frequency modulated signal is supplied to the antenna 38 via the SPDT switch 54 and transmitted from the antenna 38.

[0049] While the drive signal is at logical low, the received signal received via the antenna 38 is supplied to the reception switch 42 via the SPDT switch 54. The reception switch 42 and the mixer 52 are supplied with a signal having a frequency N^*f_{SW} output from a switch drive signal source 66. Accordingly, while the SPDT switch 54 is connected to the reception switch 42, the reception switch 42 is opened or closed at the frequency N^*f_{SW}. While the reception switch 42 is closed, the received signal received via the antenna 38 is supplied to the reception mixer 34 via the SPDT switch 54 and the reception switch 42. The reception mixer 34 produces and outputs the IF signal.

[0050] The frequency of the received signal received via the antenna 38 is given by f_0 + fδ. As a result of frequency conversion by the reception switch 42, a signal having frequencies between f_0 + fδ - N^*f_{SW} and f_0 + fδ + N^*f_{SW} is obtained. Accordingly, the reception mixer 34 produces an IF signal having frequencies between N^*f_{SW} - fδ and N^*f_{SW} + fδ. Due to the AM demodulating function of the reception mixer 34, a noise having a frequency on the order of 100 - 1000 Hz caused by ampli-

tude variation of the frequency modulated signal is contained in the IF signal. By supplying the IF signal to the band-pass filter 50 so that only the frequency band between N^*f_{SW} - fδ and N^*f_{SW} + fδ on the order of 10 - 100 MHz is allowed to pass, the noise having the frequency on the order of 100 - 1000 Hz can be removed. The IF signal is then fed to the mixer 52. The mixer 52 produces and outputs a beat signal having a frequency of fδ by mixing the IF signal having the frequencies between N^*f_{SW} - fδ and N^*f_{SW} + fδ and having the noise removed, with the drive signal having the frequency N^*f_{SW} output from the NAND circuit 64.

[0051] The switching frequency of the reception switch 42 according to the third embodiment described above is configured to be N times that of the switching frequency of the first through third embodiments so that the 1/f noise generated in the reception mixer 34 is reduced and the S/N ratio is improved.

[0052] In the third embodiment, transmission and reception switching is conducted using the drive signal having a 50% duty factor. Assuming a transmission period of τ, the drive signal frequency of f_{SW} and a maximum distance R_{max} measurable in a reception period, a reception power decreases when a distance R_t to the target object is shorter than the distance R_{max}, as shown in Fig. 15. When the distance R_t is $2^*N^*R_{max}$, where N is a natural number, the reception intensity is 0 so that the measurement is disabled. The measure $2^*N^*R_{max}$ is referred to as a fade-out point. Since the time-division transmission and reception is performed in the third embodiment, the reception intensity is in inverse proportion to the power of R_t when $R_t \leq R_{max}$. When $R_{max} \leq R_t \leq 2^*R_{max}$, the reception intensity is in inverse proportion to the sixth power of R_t.

[0053] Fig. 16 is a block diagram of a radar apparatus according to a fourth example . Referring to Fig. 16, a triangular baseband signal (Mod) having a frequency on the order of 100 - 1000 Hz is applied to the voltage controlled oscillator (VCO) 30 for frequency modulation. The resultant frequency modulated signal having a frequency f_0 on the order of 10 - 100 GHz is supplied to the single-port double-throw (SPDT) switch (SW) 54. A portion of the frequency modulated signal is branched off to the reception mixer 34. The SPDT switch 54 is controlled to be connected to the VCO 30 while the drive signal output from a voltage controlled oscillator (VCO) 70 is at logical high and to the reception mixer 34 while the drive signal is at logical low. The drive signal has a variable frequency f_{SW} between 9 MHz and 11 MHz, for example, and is a rectangular wave with a 50% duty factor. While the drive signal is at logical high, the frequency modulated signal is supplied to the antenna 38 via the SPDT switch 54 and transmitted from the antenna 38. While the drive signal is at logical low, the received signal received via the antenna 38 is supplied to the reception mixer 34 via the SPDT switch 54. The reception mixer 34 then produces and outputs the IF signal.

[0054] The IF signal has a noise having a frequency

below 100 Hz removed by the band-pass filter 50 and is then supplied to the mixer 52. The mixer 52 produces a beat signal having a frequency fδ by frequency con-version and outputs the beat signal.

[0055] A triangular wave as shown in Fig. 17A or a control voltage (V_{in}) having a random hopping waveform as shown in Fig. 17B is supplied to a control terminal of the voltage controlled oscillator 70. The frequency f_{SW} of the drive signal output from the voltage controlled os-cillator 70 varies between 9 MHz and 11 MHz in accord-ance with the control voltage. Accordingly, a distance to the fade-out point varies in a range between 13.64 X N m and 16.66 X N m. Therefore, the distance R_t to the target object can be properly detected. By raising a var-iation frequency at which the frequency f_{SW} of the drive signal varies so as to be at least on the order of 100 - 1000 Hz, it is possible to prevent the noise having the frequency on the order of 100 - 1000 Hz from being leaked to the IF signals due to the AM demodulating function of the reception mixer 34.

[0056] The variation frequency of the frequency f_{SW} of the drive signal as shown in Fig. 17A is suitably higher than the beat frequency derived from the relative speed and the distance with respect to the target object. An-other requirement for the variation frequency is that a variation of the distance to the target object is not in syn-chronism with a variation of the distance to the fade-out point determined by the variation frequency. For exam-ple, given that the maximum relative speed with respect to the target object is 180 km/h, fade-out points occur at varying locations in a 3 m range, when N = 1. The period of the variation of the frequency f_{SW} of the drive signal is suitably shorter than 60 msec.

[0057] Fig. 18 is a block diagram of a radar apparatus according to a fifth example present invention. Referring to Fig. 18, an oscillator (OSC) 72 outputs an oscillation having a frequency on the order of 10 - 100 GHz. The oscillation is supplied to the single-port double-throw (SPDT) switch (SW) 54. A portion of the oscillation is branched off to the reception mixer 34. The SPDT switch 54 is controlled to be connected to the OSC 72 while the drive signal output from the switch drive signal source (LO) 35 is at logical high and to the reception mixer 34 while the drive signal is at logical low. The drive signal has a frequency f_{SW} on the order of 10 - 100 MHz and is a rectangular wave with a 50% duty factor. While the drive signal is at logical high, the frequency modulated signal is supplied to the antenna 38 via the SPDT switch 54 and transmitted from the antenna 38. While the drive signal is at logical low, the received signal received via the antenna 38 is supplied to the reception mixer 34 via the SPDT switch 54. The reception mixer 34 then pro-duces and outputs the IF signal.

[0058] The IF signal has a noise having a frequency below 100 Hz removed by the band-pass filter 50 and is then supplied to the mixer 52. The mixer 52 produces a beat signal having a frequency fδ by frequency con-version and outputs the beat signal.

[0059] The fifth example described above is used as a Doppler radar capable of detecting only a relative speed with respect to the target object. For example, given that f_{SW} = 100 MHz, R_{max} = 0.75 m so that the fade-out point is 1.5 m. Generally, a Doppler radar ap-plied to an automobile is used to detect a ground speed, wherein the frequency of the drive signal can be rela-tively high because the target object (in this case, the ground) is a short distance away.

[0060] Similar to the first through fourth examples and first to this embodiments, the fifth example makes it pos-sible for the antenna 38 to be shared in transmission and reception. Thus, the cost and price of the radar ap-paratus according to these embodiments can be re-duced.

[0061] In an FMCW radar, a triangular modulating sig-nal is applied to a voltage controlled oscillator so that a signal indicated by the symbol la in Fig. 19 is transmit-ted. A signal indicated by the symbol IIa is reflected by the target object with a delay and is mixed with a portion of the transmitted wave which portion forms a local os-cillation source in the reception mixer. A minute frequen-cy difference between the reflected wave and the local oscillation source is detected by the reception mixer so that the distance to the target object is calculated. In the case of an FMCW radar, the greater the distance, that is, the greater the delay, the greater the frequency dif-ference and the higher the baseband output frequency of the received signal. If there is a difference in speed between the target object and the automobile, a Doppler shift is caused. The frequency difference that corre-sponds to the Doppler shift is observed as a beat signal. The frequency of the beat signal would generally be be-low 100 kHz if the triangular modulating signal has a fre-quency on the order of 100 - 1000 Hz, the frequency deviation of the FM modulated wave output from the voltage controlled oscillator is on the order of 10 - 100 MHz, the frequency used by the radar is on the order of 10 - 100 GHz, the distance to the target object is on the order of 100 - 1000 m, and the relative speed with re-spect to the target object is on the order of 10 - 100 km/h.

[0062] A wave indicated by the symbol IIIa of Fig. 19 represents an interference from another FMCW radar. It is very unlikely that a frequency variation of a radar of one vehicle is in synchronism with that of another vehi-cle causing an interference. Fig. 19 gives a general idea of how an interference occurs.

[0063] Fig. 20 shows a time-dependent variation of the frequency of the signal that occurs in the received signal baseband output. The solid line IIb of Fig. 20 in-dicates a beat signal generated due to the signal reflect-ed by the target object, the solid line IIIb indicates a beat signal generated due to an interfering signal, and the hatching indicates a passing band of the reception filter for improving the S/N ratio of the received signal. The cut-off frequency of the reception filter is determined by the distance and the relative speed to be detected. As mentioned before, the cut-off frequency on the order of

100 - 1000 kHz is used for the automobile radar.

[0064] The frequency of the interfering wave IIIb varies from a dc range to a frequency significantly higher than the frequency of the reception filter. The frequency of the interfering wave may vary till it is on the order of 100 - 200 MHz, in a case that the local oscillation source and the interference source have matching center frequencies, identical frequency deviations and reversed phases of the frequency variation.

[0065] Fig. 21 is a block diagram of a radar apparatus according to a sixth example . Referring to Fig. 21, a triangular modulating signal is supplied to a frequency hopping means 100. A frequency modulated signal output from the frequency hopping means 100 is supplied to a transmission antenna 102 and transmitted therefrom. A portion of the frequency modulated signal is branched off to a reception mixer 106. The signal received via a reception antenna 104 is mixed with the frequency modulated signal in the reception mixer 106 so as to produce a beat signal. The beat signal is supplied to an interference detecting means 108 and a reception filter implemented by a band-pass filter 110.

[0066] The interference detecting means 108 detects whether or not there is an interference and supplies the detection result to the frequency hopping means 100. In the event that there is an interference, the frequency hopping means 100 changes the frequency of the frequency modulated signal to a new frequency in a band where there is no interference. The band-pass filter 110, in which the cut-off frequency determined by the distance and the relative speed to be detected is set, removes unwanted frequency components from the beat signal and outputs the rectified signal. A low-pass filter may be used in place of the band-pass filter.

[0067] As shown in Fig. 22A, the interference detecting means 108 may be implemented by a band-pass filter 112 so as to detect by band separation an interfering signal having a frequency higher than that of the beat signal. That is, the signal represented by IIIb of Fig. 20 providing a frequency difference that exceeds the band of the reception filter is subject to band separation and output. A high-pass filter may be employed in place of the band-pass filter 112. A voltage controlled oscillator 114 shown in Fig. 22a forms a part of the frequency hopping means 100. A lower cut-off frequency of the band-pass filter 112 is configured to be higher than the higher cut-off frequency of the band-pass filter 110. A satisfactory attenuation is provided at a crossing point between the attenuation curves of the band-pass filters.

[0068] As shown in Fig. 22B, the band-pass filter 110 for extracting the received signal may be coupled to the output of the reception mixer 106. A comparator 116 operated by a predetermined threshold voltage may be used as the interference detecting means 108.

[0069] Generally an automobile radar outputs a power of about 10 dBm. Therefore, the reflected power provided an automobile 100 m ahead, for example, is approximately -130 dBm at best. The reflected power is in inverse proportion to the fourth power of the distance. In comparison with this, the interfering power from the opposite lane is in inverse proportion to the power of the distance and is therefore, significantly higher than the power of the received signal. As shown in Fig. 20, when an automobile radar is exposed to an interference from a radar of another automobile, a level of the beat signal caused by the interfering signal drops to the band of the reception filter for a limited period of time. When this drop occurs, the interfering signal becomes a pulse signal having a significantly higher level than the signal reflected by the target object. Thus, in the interference detecting means of Fig. 22B, the threshold voltage is set so that the comparator 116 operates at a sufficiently higher level than the level of the signal reflected by the target object.

[0070] Fig. 23 is a block diagram of the frequency hopping means (frequency varying means) 100. Referring to Fig. 23, an interference detection signal which goes to a logical high state when an interference is detected and is obtained in the interference detecting means is supplied to a rising detecting circuit 120. The rising detecting circuit 120 generates a pulse each time a rising of the interfering signal is detected. The pulses are supplied to an N-pulse counter 122 which is reset when a total of N pulses are input thereto. A ROM table 124 contains data relating to the center frequency of the hopping destination. A count output by the N-pulse counter 122 is supplied to the ROM table 124 as an address for reading M-bit data. A D/A converter 126 generates a dc signal that corresponds to the M-bit data output from the ROM table 124. An adder circuit 128 for adding the triangular modulating signal to the output signal from the D/A converter 126 is coupled to the D/A converter 126. An output from the adder circuit 128 is supplied to a voltage controlled oscillator 114.

[0071] Upon detection of an interference wave by the interference detecting means 108, the frequency hopping means is put into operation so as to shift the center frequency to a frequency band free from interference. Even when an interference is caused in the hopping destination, another step for frequency hopping is taken. Of course, the minimum interval of the frequency in hopping must be the same as or higher than the frequency deviation of the FMCW radar. For example, given that the frequency deviation is 75 MHz, and the assigned frequency bandwidth is 1 GHz, the hopping frequency interval is 75 MHz at the minimum. A total of thirteen channels are available as hopping destination frequencies.

[0072] Fig. 24 is a block diagram of a radar apparatus according to a seventh example . Referring to Fig. 24, a triangular modulating signal is supplied to the frequency hopping means 100 and then to a switch 130 coupled to the output of the frequency hopping means 100. When the switch is closed, a frequency modulated signal is supplied to the transmission antenna 102 and transmitted therefrom. A portion of the frequency modulated signal is branched off to the reception mixer 106.

The signal received via the reception antenna 104 is mixed by the reception mixer 106 with the frequency modulated signal so as to produce a beat signal. The beat signal is supplied to the interference detecting means 108 and a reception filter implemented by the band-pass filter 110.

[0073] The interference detecting means 108 detects whether or not there is an interference and supplies the detection result to the frequency hopping means 100. In the event that there is an interference, the frequency hopping means 100 changes the frequency of the frequency modulated signal to a new frequency in a band where there is no interference. The band-pass filter 110, in which the cut-off frequency determined by the distance and the relative speed to be detected is set, removes unwanted frequency components from the baseband signal and outputs the resultant signal.

[0074] In the seventh example, a determination is made before transmission as to whether or not there is an interference. In the event that there is an interference, the frequency hopping means 100 changes the center frequency of the transmitted signal. When the interference is no longer present, the switch 130 is closed so that the transmission is started. With this arrangement, it is possible to select a transmission frequency free from interference.

[0075] Fig. 25 is a block diagram of a radar apparatus according to an eighth example . The construction of the eighth example is almost the same as the construction shown in Fig. 21, a difference being that the modulating signal supplied to the frequency hopping means 100 is a constant-level dc signal instead of a triangular wave. That is, the radar as shown in Fig. 25 is a Doppler radar. A Doppler radar is used to detect the ground speed and is not used to measure a distance. A Doppler radar is constructed of a transmission oscillation source oscillating at a constant frequency, a local oscillation source provided by branching a portion of the oscillation of the transmission oscillation source, and a reception frequency converter. Figs. 19 and 20 illustrate how an interference occurs in the radar apparatus according to the eighth example. That is, considering a case where an FMCW radar causes an interference in another FMCW radar, the description as given with reference to Figs. 21 - 23 applies to the apparatus of Fig. 25.

Claims

1. A vehicle radar apparatus comprising: an oscillator (30) that generates a frequency modulated signal; and a reception mixer (34), coupled to said oscillator, that generates an IF signal by mixing the frequency modulated signal and a received signal formed by the frequency modulated signal reflected from a target, the IF signal indicating a distance to the target and a relative speed of the target, wherein said vehicle-mounted radar appara-

tus further comprises:

> a single antenna (38);
> antenna sharing means (36) connected to said single antenna (38); and
> a switching means (32, 42, 54) adapted to switch said antenna alternatingly between a transmission mode in which said antenna transmits the frequency modulated signal, and a reception mode in which said antenna receives the received signal, in response to a drive signal wherein said drive signal causes said switching means (32, 42, 54) to alternate between said transmission mode and said reception mode at a first switching frequency in excess of double a modulating frequency of said frequency modulated signal that is transmitted; and **characterised by** further comprising a reception switch (42) for supplying said received signal to said reception mixer (34), wherein said reception switch is subdected to switching at a second switching frequency which is an integer multiple of said first switching frequency.

2. A vehicle-mounted radar apparatus as claimed in Claim 1, **characterized in that** means are provided to further mix the mixed signal with a switching signal having said second switching frequency.

3. The radar apparatus as claimed in Claim 1, **characterized in** further comprising:

> and wherein said switching means comprises a transmission switch (32) for supplying said frequency modulated signal to said antenna sharing means (36); and
> said reception switch (42) for supplying a received signal received via said antenna sharing means (36) to said reception mixer and said apparatus further **characterized by** being adapted to effect switching between said transmission mode and said reception mode by driving one of said transmission switch and said reception switch with said drive signal, and driving another of said transmission switch and said reception switch with an inverted said drive signal.

4. The radar apparatus as claimed in Claim 3, **characterized in that** said antenna sharing means (36) is implemented by a circulator.

5. The radar apparatus as claimed in Claim 3, **characterized in that** said antenna sharing means (36) is implemented by a branch circuit.

6. The radar apparatus as claimed in Claim 1, **char-**

acterized in that said switching means (32, 42, 54) further comprises a single-port double-throw switch (54) for connecting said single antenna (38) to one of said oscillator (30) and said reception mixer (34).

7. The radar apparatus as claimed in Claim 2, **characterized in** said switching means (32, 42, 54) further comprising a single-port double-throw switch (54) for connecting said single antenna (38) to one of said oscillator (30) or said reception mixer (34).

8. The radar apparatus as claimed in Claim 1, **characterized in that** said drive signal has a frequency on the order of 10-100MHz and a rectangular waveform with a given duty factor.

Patentansprüche

1. Fahrzeug-Radareinrichtung mit: einem Oszillator (30), welcher ein frequenzmoduliertes Signal erzeugt; und einem Empfangsmischer (34), welcher am Oszillator gekoppelt ist, welcher ein IF-Signal durch Mischen des frequenzmodulierten Signals und eines durch Reflektion des frequenzmodulierten Signals vom Ziel gebildeten Empfangssignals erzeugt, wobei das IF-Signal einen Abstand zum Ziel und eine relative Geschwindigkeit des Ziels anzeigt,
wobei die am Fahrzeug eingebaute Radareinrichtung ferner enthält:

   eine Einzelantenne (38);

   ein Antennen-Mitbenutzungsmittel (36), welches mit der Einzelantenne (38) verbunden ist; und

   ein Umschaltmittel (32, 42, 54), welches dazu angepasst ist die Antenne abwechseind zwischen einem Übertragungsmodus, bei welchem die Antenne das frequenzmodulierte Signal überträgt, und einem Empfangsmodus, bei welchem die Antenne das Empfangssignal empfängt, in Ansprechen auf ein Antriebssignal umzuschalten, wobei das Antriebssignal das Umschaltmittel (32, 42, 54) dazu bewirkt zwischen dem Übertragungsmodus und dem Empfangsmodus bei einer ersten Umschaltfrequenz zu wechseln, welche höher ist als die doppelte Modulationsfrequenz des frequenzmodulierten Signals, welches übertragen wird, und **dadurch gekennzeichnet ist, dass** sie ferner

   einen Empfangsschalter (42) enthält, um das Empfangssignal an den Empfangsmischer (34) zuzuführen, wobei der Empfangsschalter un-

terworfen ist bei einer zweiten Umschaltfrequenz umzuschalten, welche ein ganzzahliges Vielfaches der ersten Umschaltfrequenz ist.

2. Fahrzeug-Radareinrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** Mittel bereitgestellt sind um ferner das Mischsignal mit einem Umschaltsignal zu mischen, welches die zweite Umschaltfrequenz hat.

3. Radareinrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** das Umschaltmittel enthält:

   einen Übertragungsschalter (32) zum Zuführen des frequenzmodulierten Signals an das Antennen-Mitbenutzungsmittel (36); und

   den Empfangsschalter (42) zum Zuführen eines über das Antennen-Mitbenutzungsmittel (36) empfangenen Empfangssignals an den Empfangsmischer, und wobei die Einrichtung ferner **dadurch gekennzeichnet ist, dass** sie dazu angepasst ist eine Umschaltung zwischen dem Übertragungsmodus und dem Empfangsmodus zu bewirken, indem einer aus dem Übertragungsschalter und dem Empfangsschalter mit dem Antriebssignal angetrieben wird, und indem der andere aus dem Übertragungsschalter und dem Empfangsschalter mit einer Invertierung aus dem Antriebssignal angetrieben wird.

4. Radareinrichtung nach Anspruch 3, **dadurch gekennzeichnet, dass** das Antennen-Mitbenutzungsmittel (36) durch einen Zirkulator implementiert ist.

5. Radareinrichtung nach Anspruch 3, **dadurch gekennzeichnet, dass** das Antennen-Mitbenutzungsmittel (36) durch einen Abzweigkreis implementiert ist.

6. Radareinrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** das Umschaltmittel (32, 42, 54) ferner einen einpoligen Umschalter (54) enthält, um die Einzelantenne (38) mit dem Oszillator (30) oder dem Empfangsmischer (34) zu verbinden.

7. Radareinrichtung nach Anspruch 2, **dadurch gekennzeichnet, dass** das Umschaltmittel (32, 42, 54) ferner einen einpoligen Umschalter (54) enthält, um die Einzelantenne (38) mit dem Oszillator (30) oder dem Empfangsmischer (34) zu verbinden.

8. Radareinrichtung nach Anspruch 1, **dadurch gekennzeichnet, dass** das Antriebssignal eine Frequenz im Bereich von 10-100 MHz und eine Rechteck-Wellenform mit einem vorgegebenen Tastver-

hältnis hat.

Revendications

1. Appareil radar monté sur véhicule comprenant:

    un oscillateur (30) qui produit un signal modulé en fréquence; et un mélangeur de réception (34) couplé audit oscillateur, qui produit un signal IF par mélange du signal modulé en fréquence et d'un signal reçu formé par le signal modulé en fréquence, réfléchi à partir d'une cible, le signal IF indiquant une distance par rapport à la cible et une vitesse relative de la cible,

    dans lequel ledit dispositif radar monté sur véhicule comprend en outre:

    une seule antenne (38);
    des moyens (36) se partageant l'antenne et connectés à ladite antenne unique (38); et
    des moyens de commutation (32, 42, 54) adaptés pour commuter ladite antenne alternativement entre un mode d'émission, dans lequel ladite antenne transmet le signal modulé en fréquence, et un mode de réception dans lequel ladite antenne reçoit ledit signal reçu, en réponse à un signal de commande, et dans lequel ledit signal de commande amène lesdits moyens de commutation (32, 42, 54) à alterner entre ledit mode d'émission et ledit mode de réception à une première fréquence de commutation dépassant le double d'une fréquence de modulation dudit signal modulé en fréquence qui est transmis; et

    caractérisé en ce qu'il comprend en outre:

    un commutateur de réception (42) pour envoyer ledit signal reçu audit mélangeur de réception (34), ledit commutateur de réception étant commandé pour effectuer une commutation sur une seconde fréquence de commutation qui est égale à un multiple entier de ladite première fréquence de commutation.

2. Appareil radar monté sur véhicule, selon la revendication 1, caractérisé en ce que des moyens sont prévus pour mélanger en outre le signal mélangé à un signal de commutation possédant ladite seconde fréquence de commutation.

3. Appareil radar selon la revendication 1, caractérisé en ce que lesdits moyens de commutation comprennent
    un interrupteur d'émission (32) pour envoyer ledit signal modulé en fréquence auxdits moyens

(36) de partage de l'antenne; et
    un interrupteur de réception (42) pour envoyer un signal reçu, qui est reçu par l'intermédiaire desdits (36) de partage de l'antenne audit mélangeur de réception, et
    ledit appareil étant en outre caractérisé en ce qu'il est adapté pour réaliser une commutation entre ledit mode d'émission et ledit mode de réception par commande de l'un dudit interrupteur d'émission et dudit interrupteur de réception avec ledit signal de commande, et commande de l'autre dudit interrupteur d'émission et dudit interrupteur de réception avec un signal de commande inverse dudit signal de commande.

4. Appareil radar selon la revendication 3, caractérisé en ce que lesdits moyens (36) de partage de l'antenne sont réalisés au moyen d'un circulateur.

5. Appareil radar selon la revendication 3, caractérisé en ce que lesdits moyens (36) de partage de l'antenne sont constitués par un circuit d'embranchement.

6. Appareil radar selon la revendication 1, caractérisé en ce que lesdits moyens de commutation (32, 42, 54) comprennent en outre un interrupteur uniipolaire bidirectionnel (54) servant à connecter ladite antenne unique (38) à l'un dudit oscillateur (30) et dudit mélangeur de réception (34).

7. Appareil radar selon la revendication 2, caractérisé en ce que lesdits moyens de commutation (32, 42, 54) comprennent en outre un interrupteur unipolaire bidirectionnel (54) pour connecter ladite antenne unique (38) à l'un dudit oscillateur (30) et dudit mélangeur (34).

8. Appareil radar selon la revendication 1, caractérisé en ce que ledit signal de commande possède une fréquence de l'ordre de 10-100 MHz et une forme d'onde rectangulaire ayant un taux d'impulsions donné.

FIG. 1 PRIOR ART

MOD IN → 10 VCO 11 TRANSMISSION ANTENNA

B OUT ← 12 MIX 13 RECEPTION ANTENNA
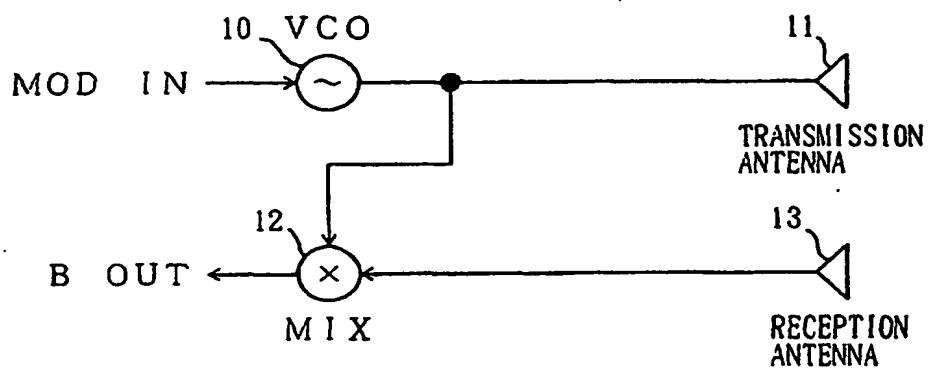
FIG. 2 PRIOR ART
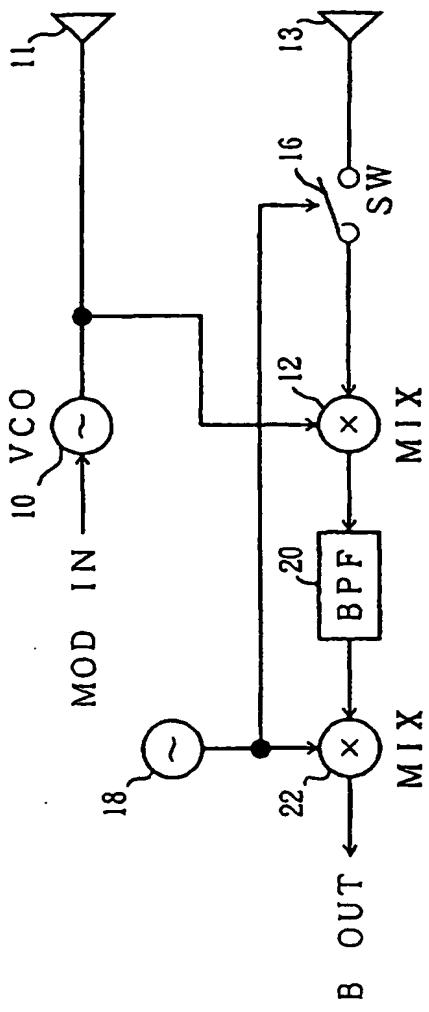
FIG. 3 PRIOR ART
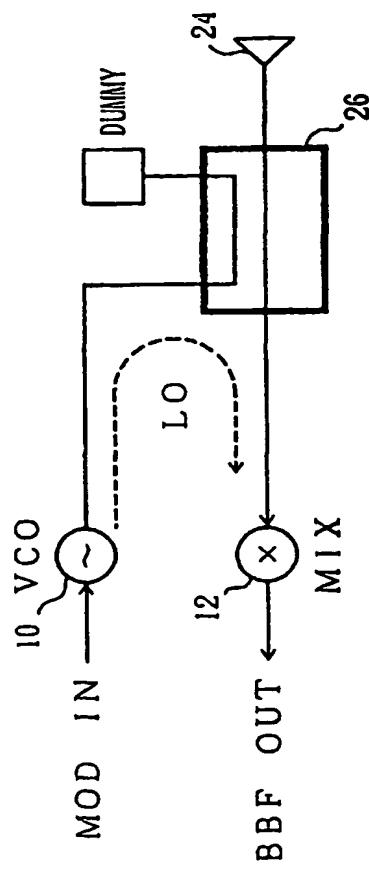
FIG. 4
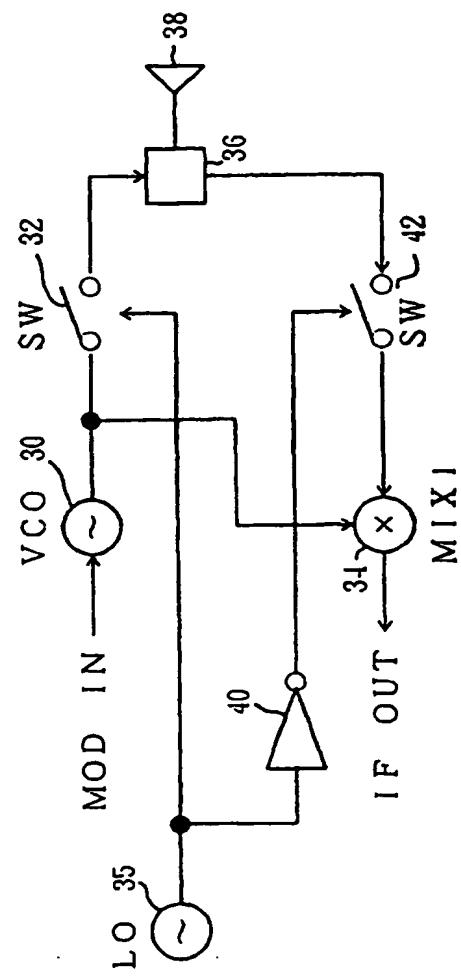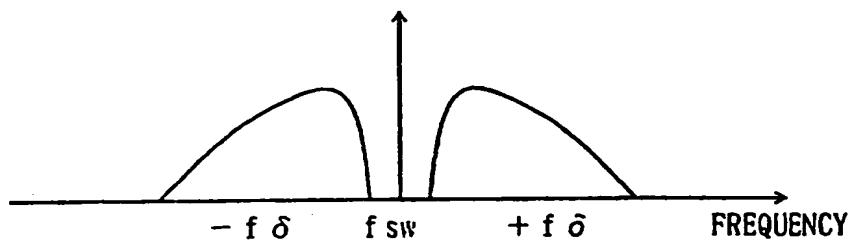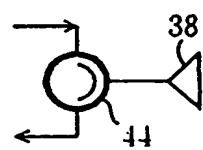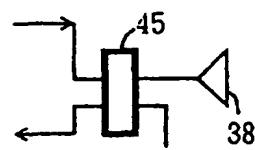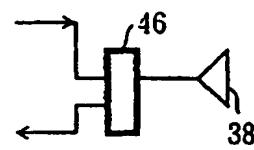
FIG. 5

−f δ   f sw   + f δ̂   FREQUENCY

FIG. 6A   FIG. 6B   FIG. 6C

FIG. 7A
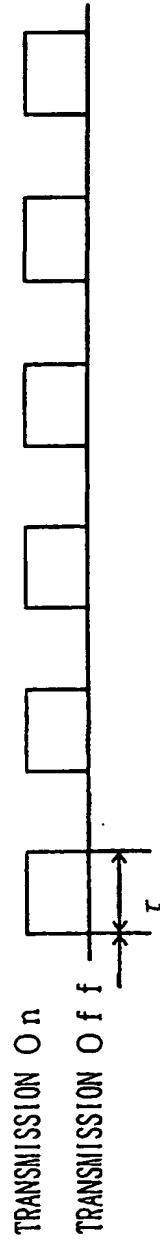
TRANSMISSION On
TRANSMISSION Off

τ

FIG. 7B

REFLECTED SIGNAL

FIG. 7C

RECEPTION STATUS
On
Off

FIG. 8

FIG. 9

FIG. 10

FIG.11

FIG. 12A

ON

OFF

τ

TRANSMISSION STATE

FIG. 12B

ON

OFF

RECEIVED SIGNAL

FIG. 12C

ON

OFF

RECEPTION STATE
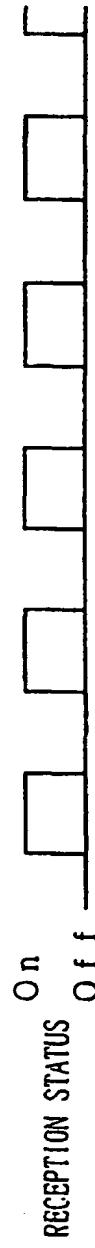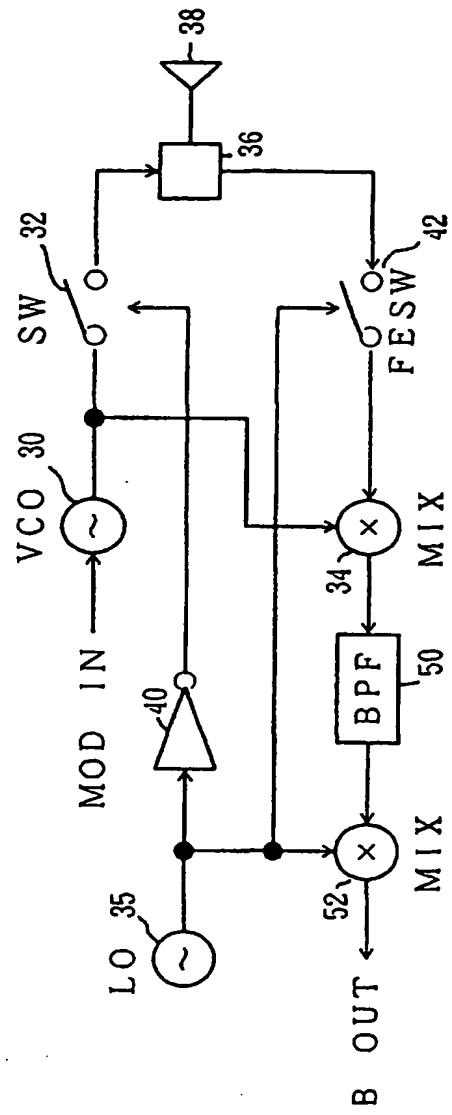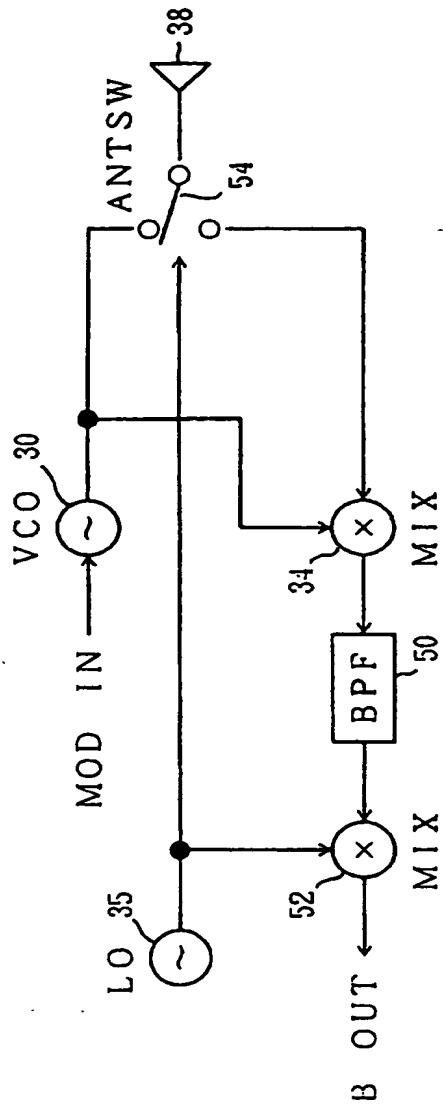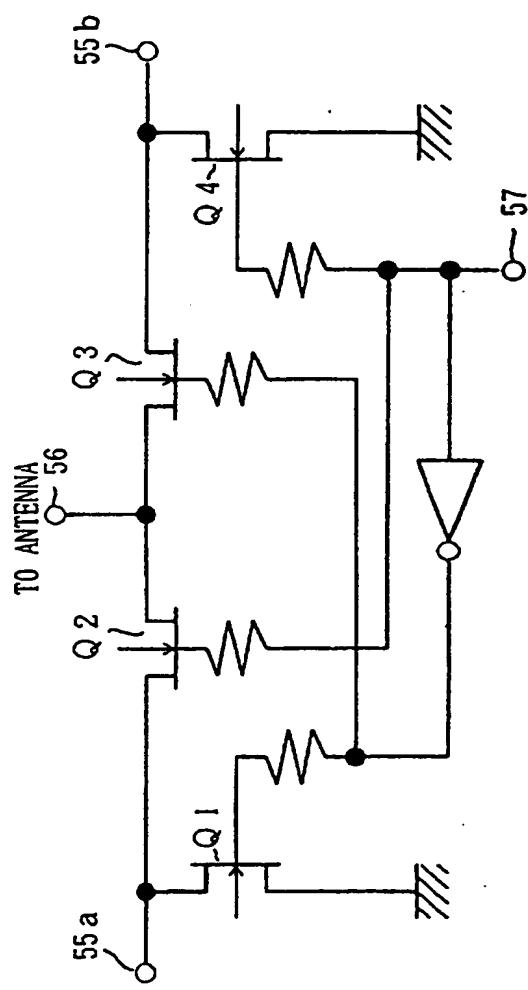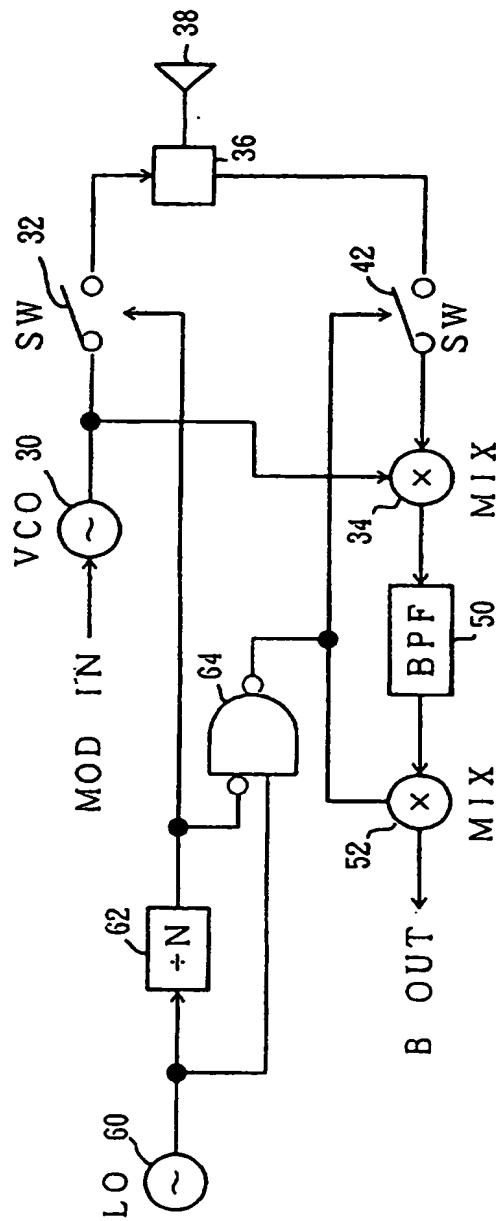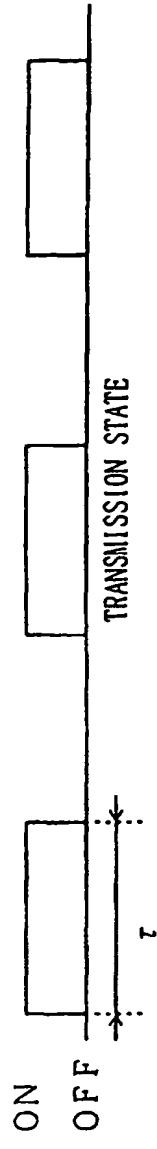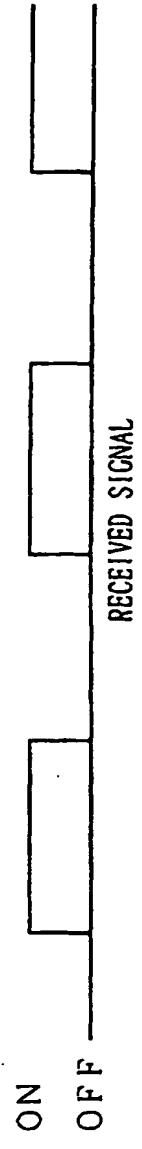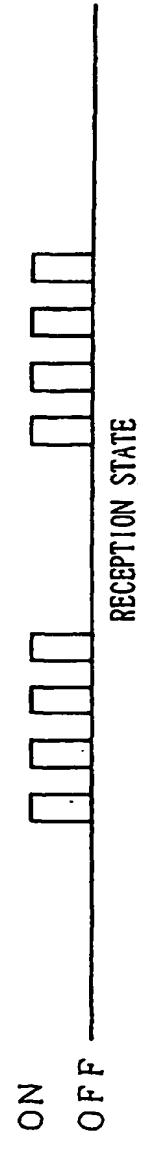
FIG. 13
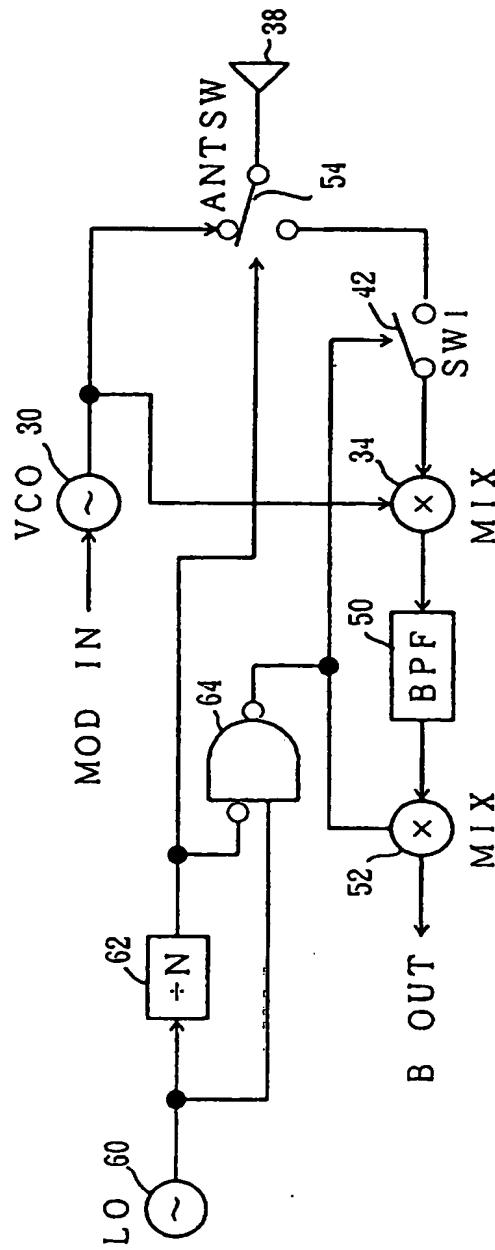
FIG. 14
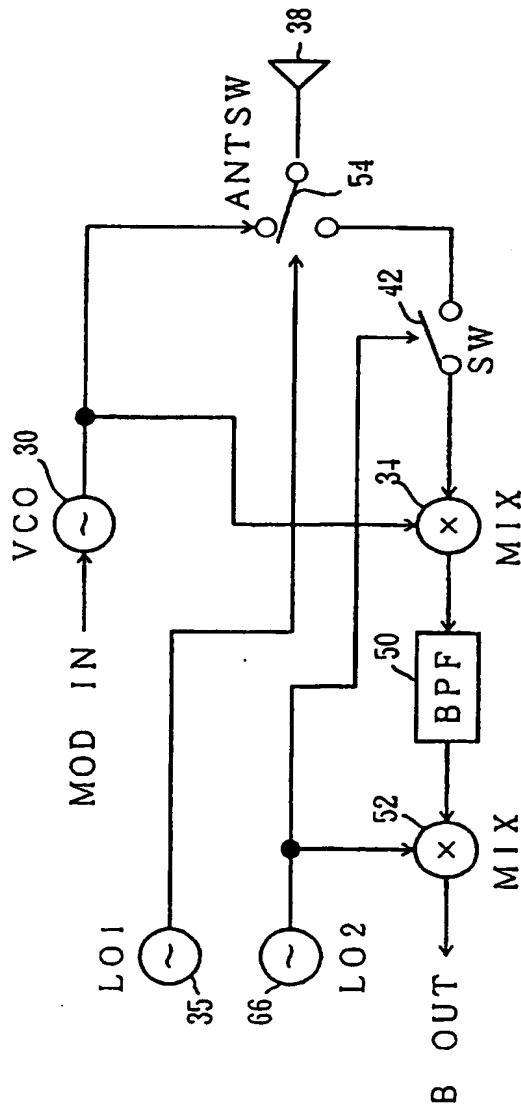
FIG. 15

τ	f sw	Rmax	RECEIVED POWER AT DIFFERENT LOCATIONS			
			1/3Rmax	1/2Rmax	2/3Rmax	Rmax
1.0 μS	500kHz	150.0m	-9.5dB	-6.0dB	-3.5dB	-0.0dB
0.5 μS	1MHz	75.0m	-9.5dB	-6.0dB	-3.5dB	-0.0dB
0.05 μS	10MHz	7.5m	-9.5dB	-6.0dB	-3.5dB	-0.0dB

FIG.16
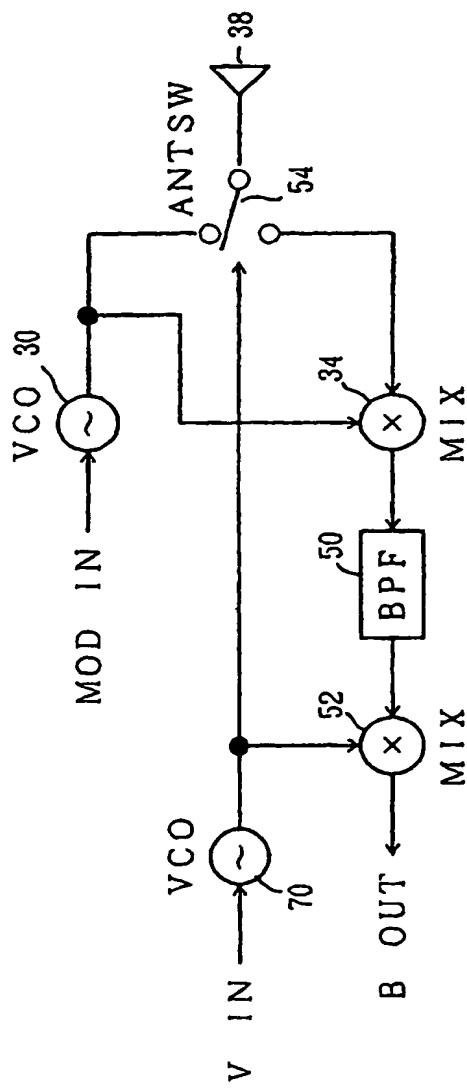
FIG. 17B

FIG. 17A
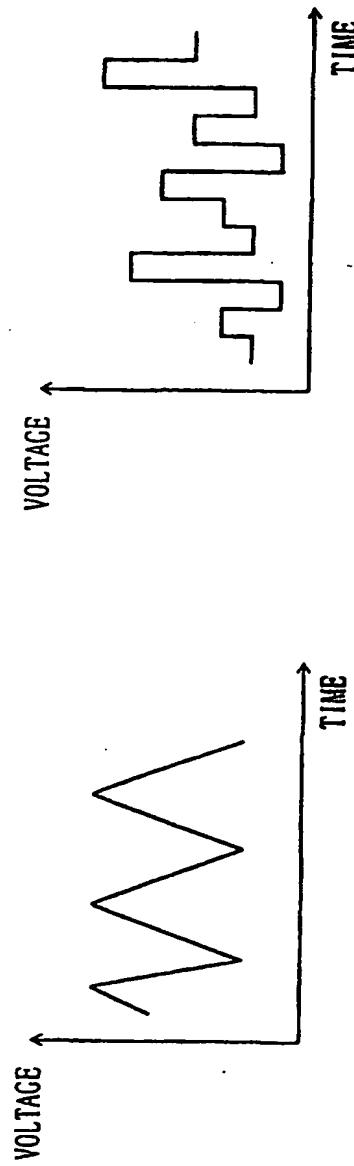
FIG. 18
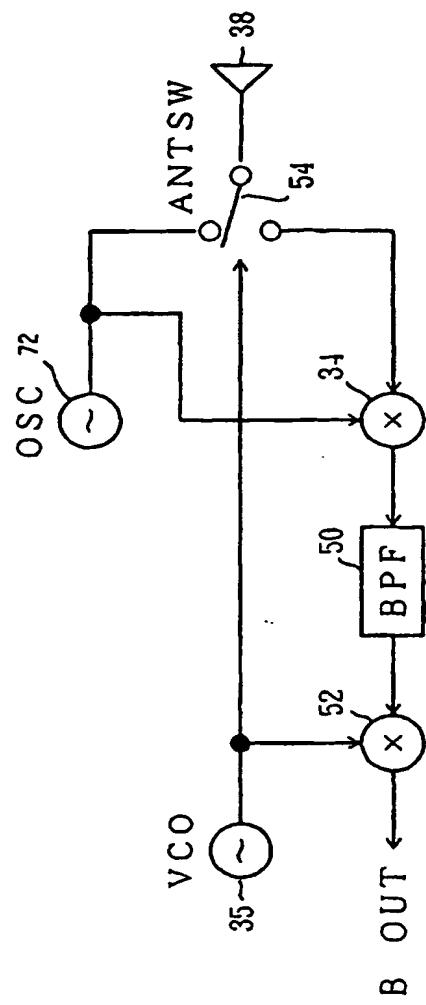
FIG. 19
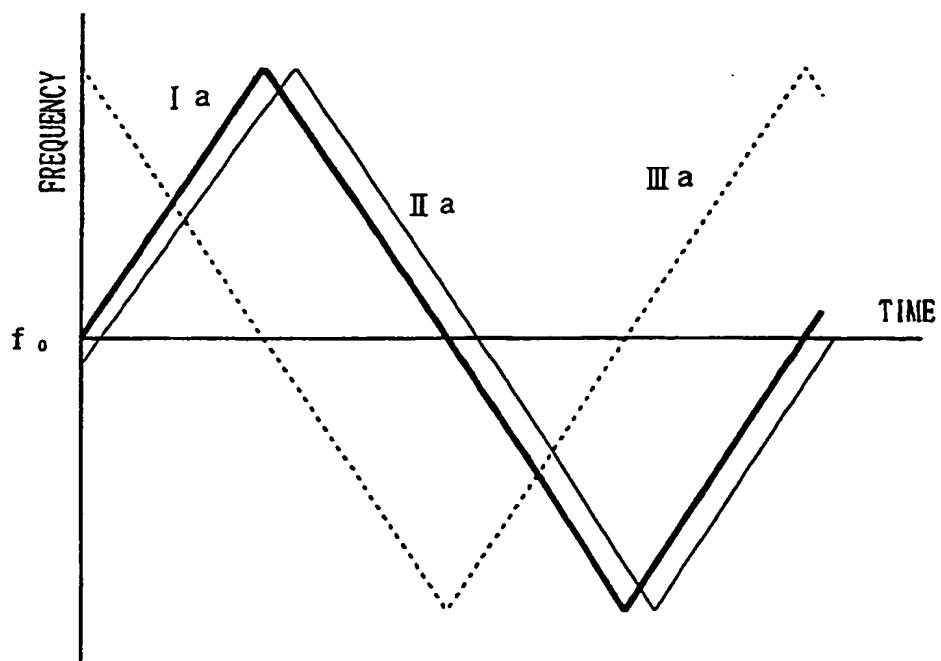
FIG. 20
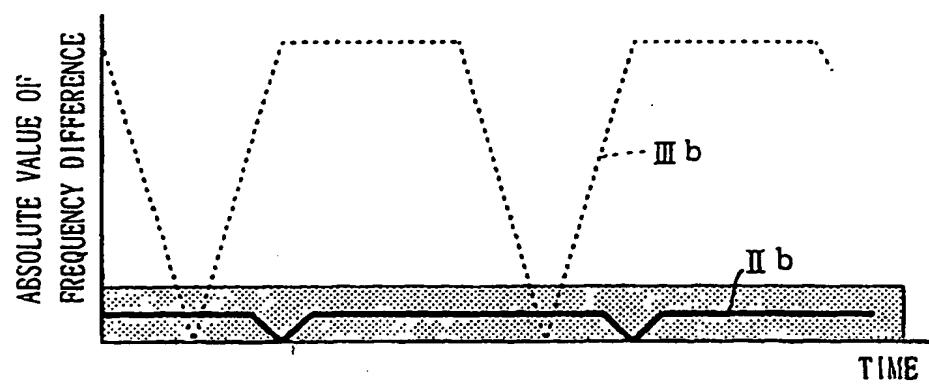
FIG. 21
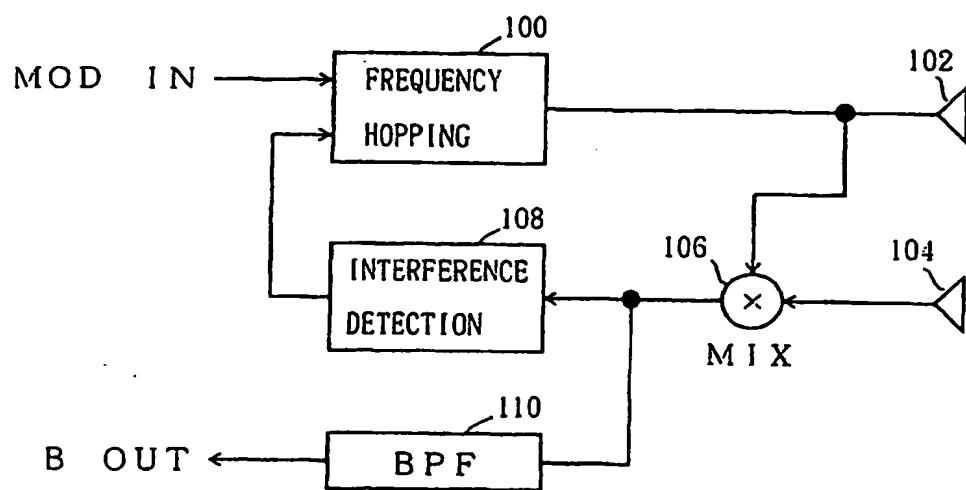
FIG. 22A

FIG. 22B

FIG. 23

FIG. 24

MOD IN $\longrightarrow$ | FREQUENCY HOPPING | 100

INTERFERENCE DETECTION | 108

130 | 102

106 | 104

$\times$ MIX

B OUT $\longleftarrow$ | BPF | 110

FIG. 25

MOD IN
(DC)

FREQUENCY
HOPPING
~100

102

INTERFERENCE
DETECTION
108

106

104

MIX

B OUT

BPF
~110
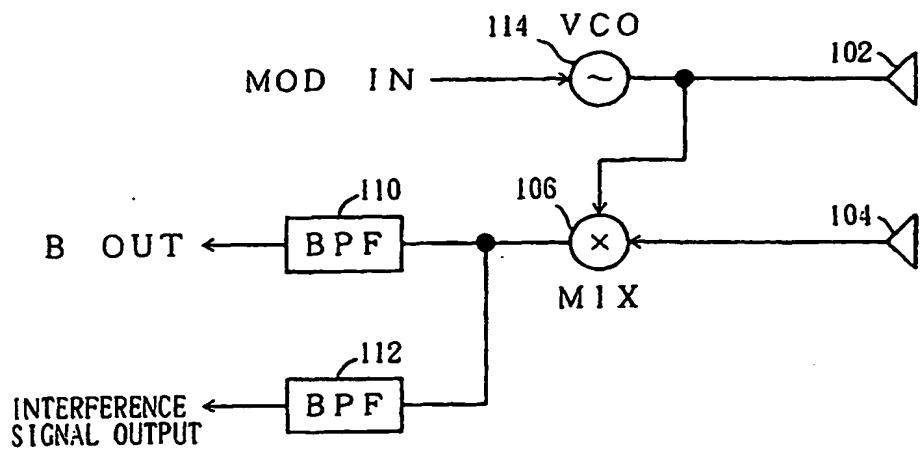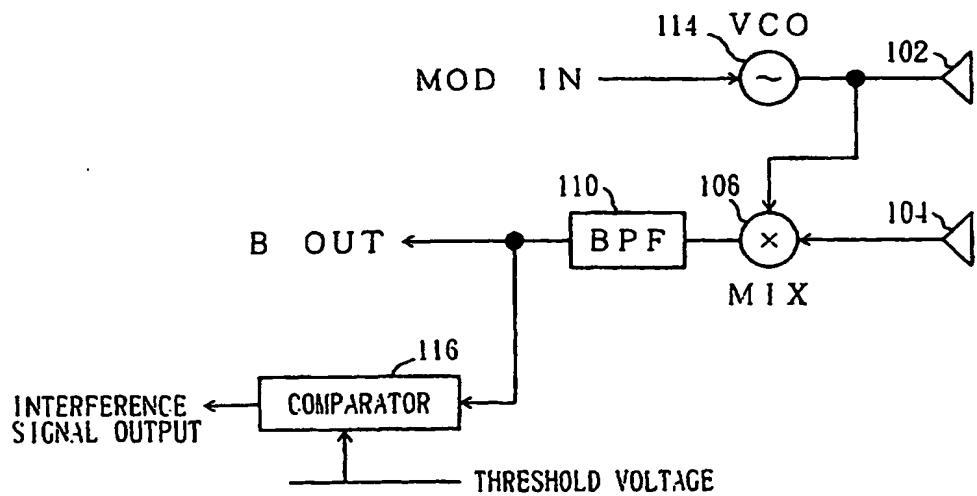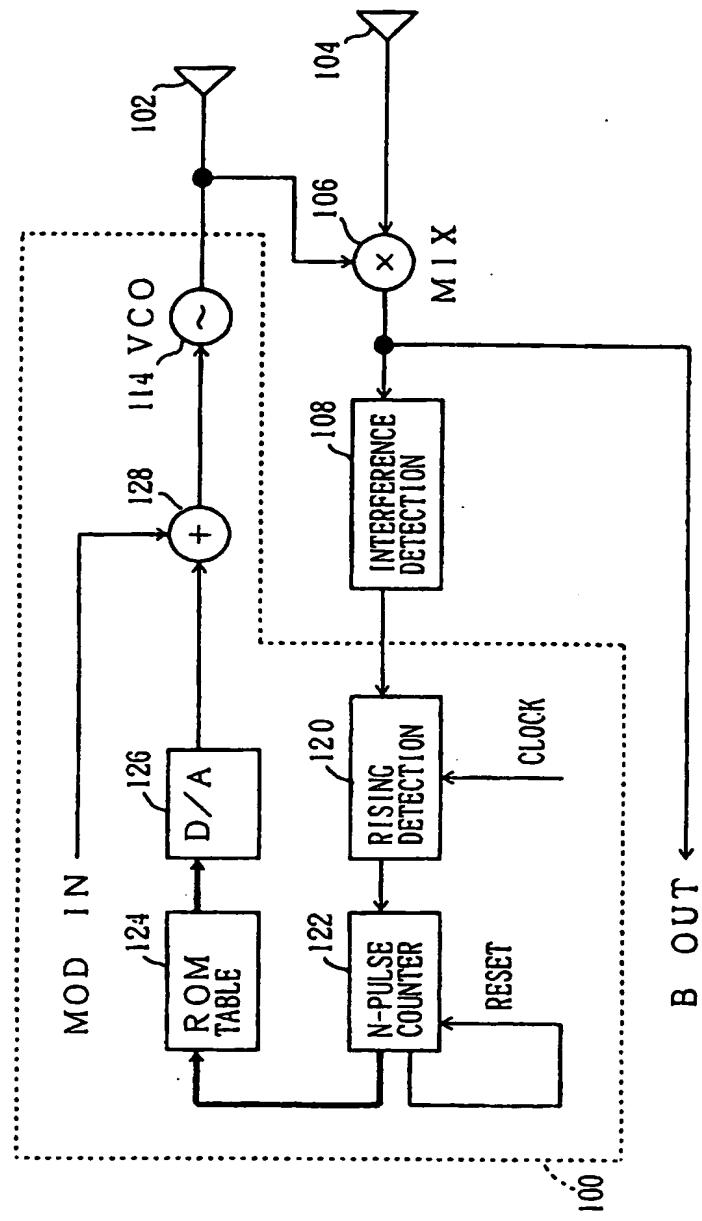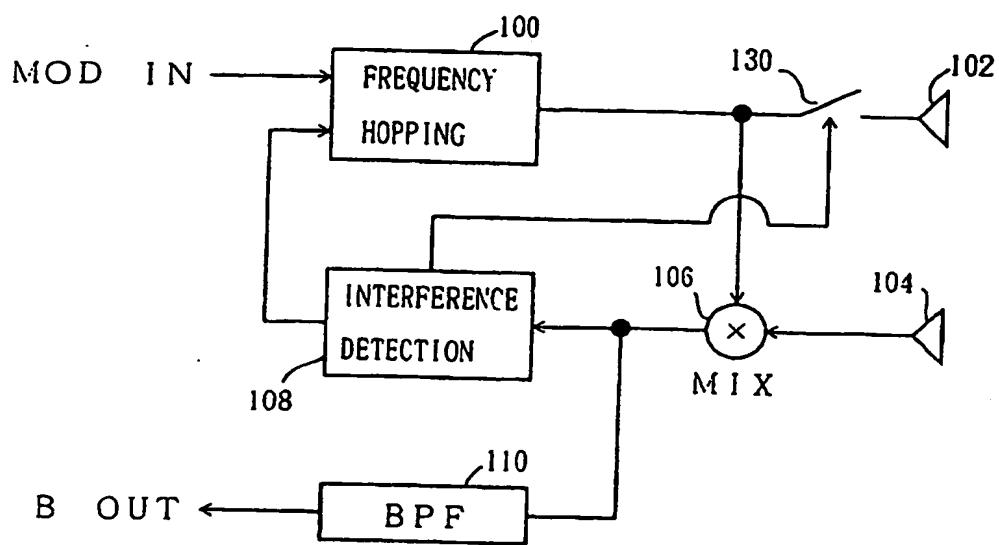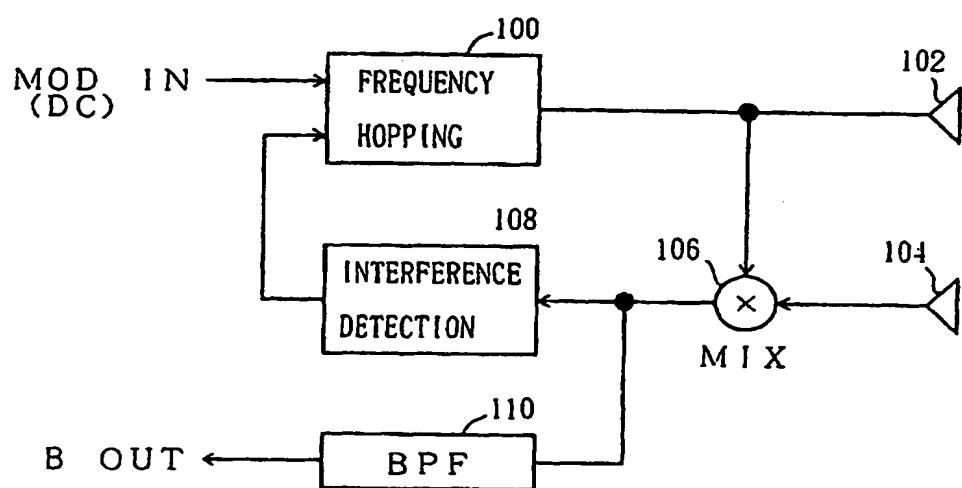
Radar apparatus with a simplified construction

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Inventor:	OKUBO NAOFUMI (JP); NINOMIYA TERUHISA (JP); SAITO TAMIO (JP); ISAJI OSAMU (JP)
Applicant:	FUJITSU LTD (JP); FUJITSU TEN LTD (JP)
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Cited documents:

- US4739330
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- US5381153
- GB2165414
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Abstract of **EP0795761**

A single antenna is used so that time-division transmission and reception is carried out in a radar apparatus for obtaining a distance and a relative speed with respect to a target object based on a beat signal obtained by transmitting a frequency modulated signal and mixing a received signal reflected by said target object with the frequency modulated signal that is transmitted.

FIG. 4